



Indiana’s academic standards for Physics I contain two standards, The Principles of Physics and Historical Perspectives of Physics. Ideas listed underneath each standard build the framework for the Physics I course.

In addition, ideas from the following four supporting themes will enable students to understand that science, mathematics, and technology are interdependent human enterprises, and that scientific knowledge and scientific thinking serve both individual and community purposes.

The Nature of Science and Technology

It is the union of science and technology that forms the scientific endeavor and that makes it so successful. Although each of these human enterprises has a character and history of its own, each is dependent on and reinforces the other. This first theme draws portraits of science and technology that emphasize their roles in the scientific endeavor and reveal some of the similarities and connections between them. In order for students to truly understand the nature of science and technology, they must model the process of scientific investigation through inquiries, fieldwork, lab work, etc. Through these experiences, students will practice designing investigations and experiments, making observations, and formulating theories based on evidence.

Scientific Thinking

There are certain thinking skills associated with science, mathematics, and technology that young people need to develop during their school years. These are mostly, but not exclusively, mathematical and logical skills that are essential tools for both formal and informal learning and for a lifetime of participation in society as a whole. Good communication is also essential in order to both receive and disseminate information and to understand others’ ideas as well as have one’s own ideas understood. Writing, in the form of journals, essays, lab reports, procedural summaries, etc., should be an integral component of students’ experience in Physics I.

The Mathematical World

Mathematics is essentially a process of thinking that involves building and applying abstract, logically connected networks of ideas. These ideas often arise from the need to solve problems in science, technology, and everyday life – problems ranging from how to model certain aspects of a complex scientific problem to how to balance a checkbook. Students should apply mathematics in scientific contexts and understand that mathematics is a tool used in science to help solve problems, make decisions, and understand the world around them.

Common Themes

Some important themes, such as systems, models, constancy, and change, pervade science, mathematics, and technology and appear over and over again, whether we are looking at ancient civilization, the human body, or a comet. These ideas transcend disciplinary boundaries and prove fruitful in explanation, in theory, in observation, and in design. These themes provide students with opportunities to engage in long-term and on-going laboratory and fieldwork, and to understand the role of change over time in studying concepts in Physics I.



Principles of Physics

Students recognize the nature and scope of physics, including its relationship to other sciences and its ability to describe the natural world. Students learn how physics describes the natural world, using quantities such as velocity, acceleration, force, energy, momentum, and charge. Through experimentation and analysis, students develop skills that enable them to understand the physical environment. They learn to make predictions about natural phenomena by using physical laws to calculate or estimate these quantities. Students learn that this description of nature can be applied to diverse phenomena at scales ranging from the subatomic to the structure of the universe and include everyday events. Students learn how the ideas they study in physics can be used in concert with the ideas of the other sciences. They also learn how physics can help to promote new technologies. Students will be able to communicate what they have learned orally, mathematically, using diagrams, and in writing.

The Properties of Matter

- P.1.1 Describe matter in terms of its fundamental constituents and be able to differentiate among those constituents.
- P.1.2 Measure or determine the physical quantities including mass, charge, pressure, volume, temperature, and density of an object or unknown sample.
- P.1.3 Describe and apply the kinetic molecular theory to the states of matter.
- P.1.4 Employ correct units in describing common physical quantities.

The Relationships Between Motion and Force

- P.1.5 Use appropriate vector and scalar quantities to solve kinematics and dynamics problems in one and two dimensions.
- P.1.6 Describe and measure motion in terms of position, time, and the derived quantities of velocity and acceleration.
- P.1.7 Use Newton's Laws (e.g., $\mathbf{F} = m\mathbf{a}$) together with the kinematic equations to predict the motion of an object.
- P.1.8 Describe the nature of centripetal force and centripetal acceleration (including the formula $a = v^2/r$), and use these ideas to predict the motion of an object.
- P.1.9 Use the conservation of energy and conservation of momentum laws to predict, both conceptually and quantitatively, the results of the interactions between objects.
- P.1.10 Demonstrate an understanding of the inverse square nature of gravitational and electrostatic forces.

The Nature of Energy

- P.1.11 Recognize energy in its different manifestations, such as kinetic ($\text{KE} = \frac{1}{2}mv^2$), gravitational potential ($\text{PE} = mgh$), thermal, chemical, nuclear, electromagnetic, or mechanical.
- P.1.12 Use the law of conservation of energy to predict the outcome(s) of an energy transformation.



- P.1.13 Use the concepts of temperature, thermal energy, transfer of thermal energy, and the mechanical equivalent of heat to predict the results of an energy transfer.
- P.1.14 Explain the relation between energy (E) and power (P). Explain the definition of the unit of power, the watt.

Momentum and Energy

- P.1.15 Distinguish between the concepts of momentum (using the formula $p = mv$) and energy.
- P.1.16 Describe circumstances under which each conservation law may be used.

The Nature of Electricity and Magnetism

- P.1.17 Describe the interaction between stationary charges using Coulomb's Law. Know that the force on a charged particle in an electrical field is qE , where E is the electric field at the position of the particle, and q is the charge of the particle.
- P.1.18 Explain the concepts of electrical charge, electrical current, electrical potential, electric field, and magnetic field. Use the definitions of the coulomb, the ampere, the volt, the volt/meter, and the tesla.
- P.1.19 Analyze simple arrangements of electrical components in series and parallel circuits. Know that any resistive element in a DC circuit dissipates energy, which heats the resistor. Calculate the power (rate of energy dissipation), using the formula $\text{Power} = IV = I^2R$.
- P.1.20 Describe electric and magnetic forces in terms of the field concept and the relationship between moving charges and magnetic fields. Know that the magnitude of the force on a moving particle with charge q in a magnetic field is $qvB\sin\alpha$, where v and B are the magnitudes of vectors \mathbf{v} and \mathbf{B} and α is the angle between \mathbf{v} and \mathbf{B} .
- P.1.21 Explain the operation of electric generators and motors in terms of Ampere's law and Faraday's law.

The Behavior of Waves

- P.1.22 Describe waves in terms of their fundamental characteristics of velocity, wavelength, frequency or period, and amplitude. Know that radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves, whose speed in a vacuum is approximately 3×10^8 m/s (186,000 miles/second).
- P.1.23 Use the principle of superposition to describe the interference effects arising from propagation of several waves through the same medium.
- P.1.24 Use the concepts of reflection, refraction, polarization, transmission, and absorption to predict the motion of waves moving through space and matter.
- P.1.25 Use the concepts of wave motion to predict conceptually and quantitatively the various properties of a simple optical system.
- P.1.26 Identify electromagnetic radiation as a wave phenomenon after observing refraction, reflection, and polarization of such radiation.



The Laws of Thermodynamics

- P.1.27 Understand that the temperature of an object is proportional to the average kinetic energy of the molecules in it and that the thermal energy is the sum of all the microscopic potential and kinetic energies.
- P.1.28 Describe the Laws of Thermodynamics, understanding that energy is conserved, heat does not move from a cooler object to a hotter one without the application of external energy, and that there is a lowest temperature, called absolute zero. Use these laws in calculations of the behavior of simple systems.

The Nature of Atomic and Subatomic Physics

- P.1.29 Describe the nuclear model of the atom in terms of mass and spatial relationships of the electrons, protons, and neutrons.
- P.1.30 Explain that the nucleus, although it contains nearly all of the mass of the atom, occupies less than the proportion of the solar system occupied by the sun. Explain that the mass of a neutron or a proton is about 2,000 times greater than the mass of an electron.
- P.1.31 Explain the role of the strong nuclear force in binding matter together.
- P.1.32 Using the concept of binding energy per nucleon, explain why a massive nucleus that fissions into two medium-mass nuclei emits energy in the process.
- P.1.33 Using the same concept, explain why two light nuclei that fuse into a more massive nucleus emit energy in the process.
- P.1.34 Understand and explain the properties of radioactive materials, including half-life, types of emissions, and the relative penetrative powers of each type.
- P.1.35 Describe sources and uses of radioactivity and nuclear energy.

Standard 2

Historical Perspectives of Physics

Students gain understanding of how the scientific enterprise operates through examples of historical events. Through the study of these events, students understand that new ideas are limited by the context in which they are conceived, are often rejected by the scientific establishment, sometimes spring from unexpected findings, and grow or transform slowly through the contributions of many different investigators.

- P.2.1 Explain that Isaac Newton created a unified view of force and motion in which motion everywhere in the universe can be explained by the same few rules. Note that his mathematical analysis of gravitational force and motion showed that planetary orbits had to be the very ellipses that Johannes Kepler had proposed two generations earlier.



- P.2.2 Describe how Newton's system was based on the concepts of mass, force, and acceleration; his three laws of motion relating to them; and a physical law stating that the force of gravity between any two objects in the universe depends only upon their masses and the distance between them.
- P.2.3 Explain that the Newtonian model made it possible to account for such diverse phenomena as tides, the orbits of the planets and moons, the motion of falling objects, and Earth's equatorial bulge.
- P.2.4 Describe how the Scottish physicist James Clerk Maxwell used Ampere's law and Faraday's law to predict the existence of electromagnetic waves and predict that light was just such a wave. Also understand that these predictions were confirmed by Heinrich Hertz, whose confirmations thus made possible the fields of radio, television, and many other technologies.
- P.2.5 Describe how among the surprising ideas of Albert Einstein's special relativity is that nothing can travel faster than the speed of light, which is the same for all observers no matter how they or the light source happen to be moving, and that the length of time interval is not the same for observers in relative motion.
- P.2.6 Explain that the special theory of relativity ($E=mc^2$) is best known for stating that any form of energy has mass and that matter itself is a form of energy.
- P.2.7 Describe how general relativity theory pictures Newton's gravitational force as a distortion of space and time.
- P.2.8 Explain that Marie and Pierre Curie made radium available to researchers all over the world, increasing the study of radioactivity and leading to the realization that one kind of atom may change into another kind, and so must be made up of smaller parts. Note that these parts were demonstrated by Rutherford, Geiger, and Marsden to be small, dense nuclei that contain protons and neutrons and are surrounded by clouds of electrons.
- P.2.9 Explain that Ernest Rutherford and his colleagues discovered that the radioactive element radon spontaneously splits itself into a slightly lighter nucleus and a very light helium nucleus.
- P.2.10 Describe how later, Austrian and German scientists showed that when uranium is struck by neutrons, it splits into two nearly equal parts plus two or three extra neutrons. Note that Lise Meitner, an Austrian physicist, was the first to point out that if these fragments added up to less mass than the original uranium nucleus, then Einstein's special relativity theory predicted that a large amount of energy would be released. Also note that Enrico Fermi, an Italian working with colleagues in the United States, showed that the extra neutrons trigger more fissions and so create a sustained chain reaction in which a prodigious amount of energy is given off.



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